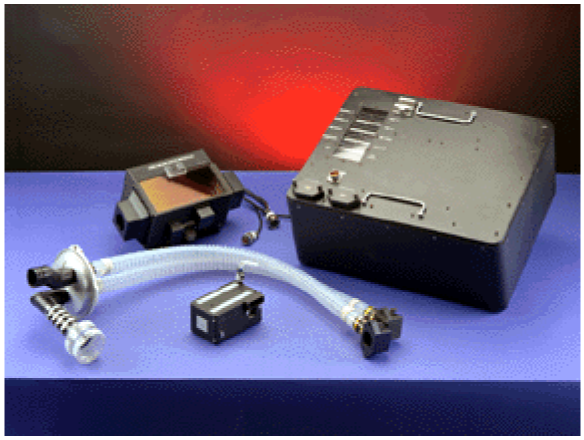
Comparative Soot Diagnostics Experiment Looks at the Smoky World of Microgravity Combustion

From an economic standpoint, soot is one of the most important combustion intermediates and products. It is a major industrial product and is the dominant medium for radiant heat transport in most flames used to generate heat and power. The nonbuoyant structure of most flames of practical interest (turbulent flames) makes the understanding of soot processes in microgravity flames important to our ability to predict fire behavior on Earth. In addition, fires in spacecraft are considered a credible possibility.

To respond to this risk, NASA has flown fire (or smoke) detectors on Skylab and the space shuttles and included them in the International Space Station design. The design of these detectors, however, was based entirely on normal gravity (1g) data. The detector used in the shuttle fleet is an ionization detector, whereas the system planned for the space station uses forward scattering of near-infrared light. The ionization detector, which is similar to smoke detectors used in homes, has a comparative advantage for submicron particulates. In fact, the space shuttle model uses a separation system that makes it blind to particles larger than a micron (believed to be dust). In the larger size range, the light-scattering detector is most sensitive.

Without microgravity smoke data, the difference in the particle size sensitivities of the two detectors cannot be evaluated. As part of the Comparative Soot Diagnostics (CSD) experiment, these systems were tested to determine their response to particulates generated during long periods of low gravity. This experiment provided the first such measurements toward understanding soot processes on Earth and for designing and implementing improved spacecraft smoke detection systems.

The objectives of CSD were to examine how particulates form from a variety of sources and to quantify the performance of several diagnostic techniques. The sources tested included four overheated materials (paper, silicone rubber, Teflon-coated (DuPont) wire, and Kapton-coated (DuPont) wires), each tested at three heating rates, and a candle tested at three air velocities. Paper, silicone rubber, and wire insulation, materials found in spacecraft crew cabins, were selected because of their different smoke properties. The candle yielded hydrocarbon soot typical of many 1g flames. Four diagnostic techniques were employed: thermophoretic sampling collected particulates for size analysis; laser light extinction measurements near the source tallied total particulate production; and laser light scattering and ionization detector measurements far from the particulate source provided data for evaluating the performance of smoke detection systems for these particulate sources.



Comparative Soot Diagnostics (CSD) hardware. The Far-Field Box contains space station and space shuttle smoke detectors. The Near-Field Module, which is placed in the Glovebox facility, contains the combustible samples.

The CSD experimental hardware consisted of two modules: the Near-Field Module and the Far-Field Box. The Near-Field Module contained the combustible sample and near-field diagnostics. The Far-Field Box contained two spacecraft smoke detectors, an exact copy of those currently used on the shuttles and a prototype International Space Station detector. Products (soot and gases) from the near-field tests were transported to the Far-Field Box and subsequently back through Teflon hoses, isolating the crew from the smoke. This project was a collaborative effort of the NASA Lewis Research Center, the NASA Marshall Space Flight Center, and the NASA Johnson Space Center.

For the majority of the samples, detectable smoke concentrations were produced and the smoke was detected by both detectors. Smoke particulate samples were successfully collected for most of the tests. Smoke particle size distributions determined from Transmission Electron Microscope data are being evaluated. In general, the light-scattering detector detected the smoke from the majority of the tests, whereas the ionization detector was less sensitive to smoke from some of the tests. Both detectors responded very well to the smoke from these sources in preflight normal-gravity tests, this suggests that the particle size distribution shifted toward larger particles.

Find out more about the Comparative Soot Diagnostic experiment.

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